ON THE CEPHENEMYIA MECHANISM AND THE DAYLIGHT–DAY CIRCUIT OF THE EARTH BY FLIGHT

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In the April, 1926, issue of the *Scientific Monthly,* the writer published an article on this subject, which was commented on by Mr. H. V. Haight in the succeeding issue of the same journal. Mr. Haight's points are very well taken, and his remarks on fuel are of especial interest and importance.

Mr. Howard S. Rappleye, of the U. S. Coast and Geodetic Survey, called the writer's attention by letter to the fact that the length of the 40th parallel is 19,103 statute miles and that of the 60th parallel 12,483 statute miles; also that, as observed by Mr. Haight in his comments, 815 miles per hour exceeds the speed of dawn, whereby a westward flight at that speed, starting from New York at dawn, would keep the flyer in darkness for the entire circuit, on the basis of the erroneous length of the parallel.

The writer was keeping strictly in mind the ordinary single daylight-day of 17 hours at a given point on the 40th parallel, like New York, in June; and the daylight-day of 18 hours on the 60th parallel, likewise at a given point. He confesses to having overlooked the fact that 815 miles per hour exceeds the speed of dawn. However, while this would in great part eliminate the sight-seeing element of the trip, flying westward on the original schedule, the result would remain the same and one would get back to New York the same date on which he left there. At the same speed of 815 miles per hour, one could travel east on the 40th parallel and experience two short daylight-days divided by a short night, all on the same date at New York. But by the revised length of the 40th parallel we see that the circuit either way at this speed would consume nearly 23½ hours. On the 50th parallel it would consume little over 19½ hours, and on the 60th parallel little less than 15 1–3 hours.

A speed of only 466 miles per hour is necessary to circle the earth westward on the 40th parallel of north latitude in June from dawn to dusk of the aviator's day, since the flyer would have 41 hours of continuous daylight on such trip, and only about 385 miles per hour will accomplish this circuit on the 50th parallel; while about 297 miles per hour will do the same on the 60th parallel, where the flyer would have at least 42 hours of continuous daylight. This is not a single daylight-day from the viewpoint of a fixed locality, but a double daylight-day; yet, from the viewpoint of the flyer, constantly moving westward, it amounts to a single daylight-day in effect. It is of extreme interest as affording a mark that should be reached within the next decade; while the more remote future holds the possibility of riding the tail of high noon or speeding on the wings of the morning halfway between the equator and either pole. It can not be denied that the double daylight-day westward circuit will attain great popularity before the single daylight-day circuit is realized.

The new trend of experimental invention is toward the development of the ornithopter type of air machine. This is the flapping-wing type. Many facts point to the possibility that this type, or an acceleration of it, will eventually materialize and outdo the airplane in general utility and effectiveness. In view of this, the structure of the Cephenemyia wing takes on an increased importance. The flapping wing of the bird has a very different structure from the vibrating wing of the fly, and extended experiment may easily result in demonstrating the superiority of the latter for purposes of mechanical flight. The fly-wing type of air machine may be termed Myiopter.

The main object of this article is to call attention to the peculiar structure of the fly wing. The Cephenemyia wing has never been critically studied, but the *Musca vomitoria* or blowfly wing has been quite exhaustively described by Lowne and Ritter. The main features of the two should be much the same, but it is quite certain that the Cephenemyia wing is far more perfected in detail. The chief mechanical interest in the matter hinges on the unique method of articulation of the fly wing with the body. This, unlike the articulation of the bird wing, is accomplished by seven peculiarly shaped sclerites assembled on a particular plan and massed together in the wing base. These sclerites, through their form and system of coordination, function in allowing the greatest freedom of movement combined with the utmost rapidity of stroke.

Below are the names of these seven sclerites, with a brief description of the characters and functions of each:

1. *Epaulet.*—A subcircular scalelike sclerite fringed with bristles and set at the extreme base of the wing. It springs from the margin of the pre-epaulet, which is a hoodlike pouch of the epipleural body-plate, and articulates with the dens and the coracoid. It protects the wing joint in front.

2. *Subepaulet.*—A bare subscalelike sclerite lying beneath and distally to the epaulet. It springs also from the margin of the pre-epaulet, gives off a process to connect with the coracoid, and articulates with the costa or outer marginal rib of the wing. It gives free movement to the costa.

3. *Dens.*—A sclerite consisting of a compact body with four protuberances or processes, of which only the main one or dentate process is externally visible. It articulates anteriorly with the epaulet, and posteriorly with the unguiculus. It increases the freedom of movement of the costal border of the wing.

4. *Coracoid.*—A sclerite wedged in between the epaulet and the unguiculus. It tends to prevent the dislocation of the remigium, which see further on.

5. *Unguiculus.*—A peculiarly shaped sclerite consisting of a horizontal and a vertical plate and a stirruplike structure. Its horizontal plate is wedged between the coracoid and the dentate process of the dens. Its vertical plate lies between the dentate process of the dens and the rest of the propterygium (epaulet and subepaulet). The stirruplike portion projects below the wing base in the form of a hook which articulates with the epipleural body-plate. It provides extreme freedom of wing movement.

6. *Hypopterygium.*—A curved capitate sclerite surrounded by an erectile papilla and capped by an elastic hood of hyaline tissue. It articulates proximally with the posterior edge of the pre-epaulet. It functions during extension of the wing by inter-

position between the articulation of the preceding sclerites with the remigium.

The six sclerites above described constitute the anterior root of the wing. The epaulet, subepaulet and dens comprise the propterygium or front subsystem; the coracoid and unguiculus comprise the mesopterygium or mid-subsystem, and the hypopterygium alone forms the hind subsystem of the anterior root.

The epaulet and subepaulet, taken together, form a series which springs from the pre-epaulet and articulates distally with the costa or front rib of the wing. The dens, coracoid, unguiculus and hypopterygium form a series which articulates proximally as a whole with the body projection known as the head of the anterior alar apophysis of the postscutum, and distally with the remigium or common root of the subcostal and radial trunks of the wing ribbing.

7. *Metapterygium.*—This sclerite forms the entire system of the posterior root of the wing. It consists of two limbs united at an obtuse angle, the anterior limb being called the deltoid and the posterior limb the humerus. It articulates proximally with the terminal socket of the posterior alar apophysis or inferior process of the rim of the scutellum, and distally with the patagium or common root of the medial, cubital and axillary trunks of the wing ribbing. It gives free movement to the inner border of the wing.

To supplement this brief survey of the fly wing articulation, it is necessary to make some mention of the muscles which control the wing. These are classed in two series, the great thoracic and the alar articulation muscles.

The great thoracic muscles are enormously developed and nearly fill the whole thoracic cavity of the fly. They furnish the real wing power and consist of nine pairs of very large muscle-bands. They comprise six pairs of nearly longitudinal *dorsals* in the central portion of the thorax, and three pairs of nearly vertical *sternodorsals* outside these in the lateral portions of the thorax. The contraction of the dorsals acts by increasing the convexity of the roof of the thorax, raising certain of the exoskeletal wing articulation processes, which in turn lower certain other like processes that act as levers to depress the wings. The contraction of the sternodorsals raises the wings by vertical compression of the thorax, acting conversely to the dorsals on the respective processes.

The alar articulation muscles form an elaborate series of ten pairs controlling the wing roots. Their names and functions are given below. Complete origins, attachments, courses and insertions can not be given, since these would entail descriptions of the many thoracic-wall sclerites and processes, which are beyond the limits of the present article. But enough is given to furnish an index to the wing root articulation musculature.

1. *Adductors.*—These are complex, being partly muscle, partly tendon traversing the postalar foramen, and partly postalar ligament, the last stretched between and inserted in four different processes of the wing base and body-wall. They function in drawing the wings back toward the body, serving to restore them from the position of flight to that of rest.

2. *First abductors.*—Delta-shaped muscles broadening distally and inserted in the cruriform process of the parapteron, which is mainly an internal sclerite of the thoracic wall. They function in drawing the wings horizontally forward.

3. *Second abductors.*—These are the strongest of all the alar articulation muscles and are also delta-shaped. Each lies beneath the first abductor of its side, is continued in a tendon under the parapteron, traverses the postalar foramen and is inserted on the front border of the wing joint. They function with the preceding in drawing the wings horizontally forward, one pair effecting this while the wings are depressed, thus causing the forward movement both during and after the down stroke of the wing.

4. *First levators.*—Delta-shaped muscles which pass into a long delicate tendon that is inserted into one of the processes of the wing base. Their contraction depresses the process, causing the wings to rise and at the same time drawing them somewhat backward.

5. *Second levators.*—Rhombic muscles passing into a strong tendon which is inserted into the same process in the wing base with the preceding. They function with the first levators in raising the wings and drawing them somewhat backward, their contraction depressing the process.

6. *First supinators.*—Delta-shaped muscles passing into a tendon which is inserted into the anal ligament. They function in depressing the anal portion of the wings.

7. *Second supinators.*—Also delta-shaped, each arising at an apodeme behind the first supinator of its side, being then continued in a long tendon which passes through the postalar foramen and is inserted in the anal ligament. They function with the first supinators in depressing the anal portion of the wings.

8. *Pronators.*—Slender delta-shaped muscles, each passing with the second abductor tendon of its side under the parapteron, being then continued in a tendon which traverses the prealar foramen and is inserted on the wing joint. They function in depressing the anterior border of the wing, apparently increasing the wing torsion during the down stroke. These and the two pairs of supinators appear to produce the torsion of the wing surface and change its degree as required.

9. *Graciles.*—Small oval muscles arising from the parapteron and continued in a delicate tendon which is inserted in a process of the body wall. Their function is obscure.

10. *Anonymi.*—Very delicate and covering the episternum. Function unknown.

Fuller details of the above sclerites and muscles in *Musca vomitoria* may be found in B. T. Lowne's "Anatomy and Physiology of the Blowfly," 2 vols., London (1892–95); and in W. Ritter's "Flying Apparatus of the Blowfly," Smithsonian Miscellaneous Collections, vol. LVI, Washington (1911). The Cephenemyia wing, however, will certainly be found to differ in important details, and must be thoroughly studied on its own. The *Musca vomitoria* mechanism merely paves the way to a realization of the complexity of the Cephenemyia mechanism.

Regarding the speeds of Cephenemyia, the idea of a fly overtaking a bullet is a painful mental pill to swallow, as a friend has quaintly written me, yet these flies can probably do that to an old-fashioned musket ball. They could probably have kept up with the shells that the German big-bertha shot into Paris during the world war. The males are faster than the females, since they must overtake the latter for coition. Then the males habitually fly at higher altitudes than the gravid females, and thus encounter less friction which enables them to attain greater speeds. Besides the gravid females are heavily laden with ova and young, which must make them slower than the males. At 7,000-foot levels in the Sierra Madre valleys of western Chihuahua I have seen the gravid females pass while on the search for hosts at a velocity of well over 300 yards per second—allowing a slight perception of color and form, but only a blurred glimpse. On the other hand, on 12,000-foot summits in New Mexico I have seen pass me at an incredible velocity what were quite certainly the males of Cephenemyia. I could barely distinguish that something had passed—only a brownish blur in the air of about the right size for these flies and without sense of form. As closely as I can estimate, their speed must have approximated 400 yards per second.

Both the bird and the fly exemplify in a general way the flapping wing movement, but the fly wing is far speedier in its up-and-down movements and must be termed the vibrating wing. The bird has an internal skeleton, hence its wing articulation is internal to the muscular system. The fly has an external skeleton, thus its wing articulation is external, the muscles being protected inside the skeletal structures. The latter type alone admits of the peculiar complex wing base of the fly. These constitute the radical differences between the ornithopter and myiopter types of mechanism. The external articulation appears to be the more efficient. Air machines will, therefore, probably attain greater efficiency if modeled on the myiopter plan.

New construction materials of great strength and resiliency, new fuels of superior concentration, and new and superefficient motors are all three coming to the front at the present moment. With these aids, the myiopter type of machine should far excel anything heretofore accomplished in the air, and may well aim at exceeding the speed of the dawn.

The idea of beating the speed of the earth's axial revolution holds fascinating possibilities. Short stops could be made at various points when necessary to replenish power and supplies as well as for frequent change of machines at regular bases, and one could still keep abreast on the average with the westward advance of midday. As the daylight-day shortens in the northern hemisphere, one could follow the sun across the equator into the southern hemisphere with its long December days of daylight, thereby keeping the glowing orb always in the zenith. We can go Joshua one better by causing the sun to recede eastward from the aviator's viewpoint, provided only that we can attain the alleged speed of Cephenemyia.